Evaluation of VCSEL Mounted on CVD Diamond Substrates

Home

Current Projects

Past Topics in...

TVA Library

Validation Methods

TVA Group Members

Links

Site Index

Harry C. Shaw
301-286-6616
Associate Branch Head
Component Technology and Radiation Effects Branch
Goddard Space Flight Center
harry.c.shaw@gsfc.nasa.gov

Melanie N. Ott
301-286-0127
Director, Advanced Photonic Interconnection Manufacturing Laboratory
Director, Technology Validation Laboratory for Photonics
Sigma Research and Engineering
Goddard Space Flight Center
Melanie.Ott@gsfc.nasa.gov

Evaluation of Vertical Cavity Surface Emitting Lasers (VCSEL) mounted on CVD Diamond Substrates

Goddard Space Flight Center

National Aeronautics and Space Administration

SIGMA SPACE

APPLIED ENGINEERING AND TECHNOLOGY DIRECTORATE
NASA GODDARD SPACE FLIGHT CENTER

Evaluation of Vertical Cavity Surface Emitting Lasers (VCSEL) mounted on CVD Diamond Substrates

NASA/GSFC Component Technology and Radiation Effects Branch

September 21, 2001

Contact: Melanie Ott, **Sigma Research and Engineering, (301)-286-0127**
Harry Shaw, NASA/GSFC, 301-286-6616

Introduction

This report summarizes the evaluation of 850 nm VCSELs manufactured by Emcore. The purpose of the evaluation was determine if the superior thermal properties of diamond as a substrate would improve the performance and reliability of the mounted VCSELs. Four VCSELs were mounted to diamond substrates and four more were mounted directly to Kovar headers and subjected accelerated voltage and current overdrive conditions. The diamond substrates provided a significant reliability advantage, however, there were unexplained shifts in the spectral properties of the devices. These mode shifts could be the subject of further investigation.

Bare die were purchased and mounted onto gold plated CVD diamond substrates 500um in thickness. Die attach was performed using 84-1 conductive epoxy (Ablestik). 1 mil Au thermosonic wire bonding was used. The individual die were mounted on 250 um centers. The substrates were mounted onto TO-8 gold plated kovar headers. A MTP ribbon cable was used as a waveguide to the HP7095 Optical Spectrum Analyzer (OSA) and HP 8153 Lightwave Multimeters.

4 VCSELs were mounted directly on the TO-8 cans to permit comparison of the performance with and without diamond substrates. Due to alignment fiber-VCSEL alignment difficulties, mating and demating of the ribbon cable was kept to a minimum.

Figures 1 and 2 depict the VCSELs unmounted and mounted on diamond. The devices used in the evaluation are no longer available as discrete parts. The next generation is preferred because the devices are available as monolithic arrays. The arrays are preferred because the optical alignment problems with the discrete devices can be eliminated. Figure 2a depicts the bare diamond substrate. Figure 2b is a block diagram of the test setup.

Figure 1. 850 nm VCSEL with 3 apertures

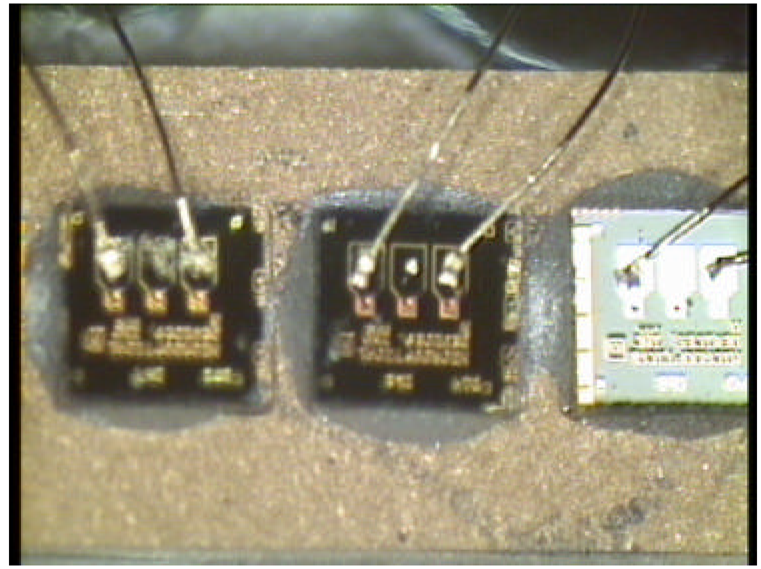


Figure 2. VCSELs mounted to CVD diamond substrates.

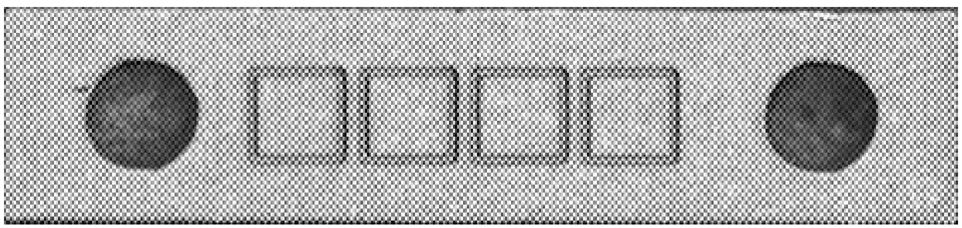


Figure 2a. Bare diamond substrate. Metalization is Ti/Pt/Au. Dimensions: 0.256” x 0.06” x 0.017” (thickness)

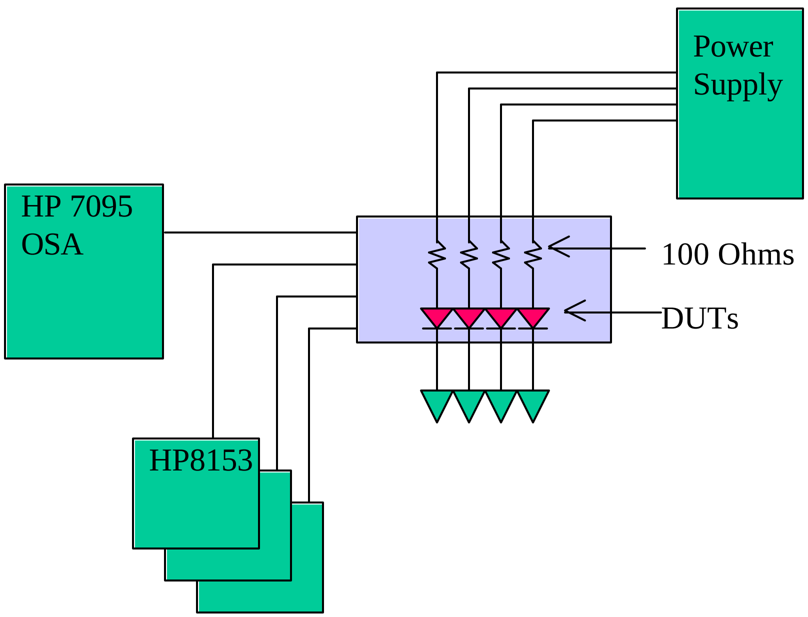


Figure 2b. Electrical Test Block Diagram

1. VCSEL Optical output power vs bias

Each of the 4 VCSELs are driven by single power supply through a 100 ohm resistor. Table 1 depicts the power output response of the a typical device under swept bias. This device is mounted directly to the TO-8 can

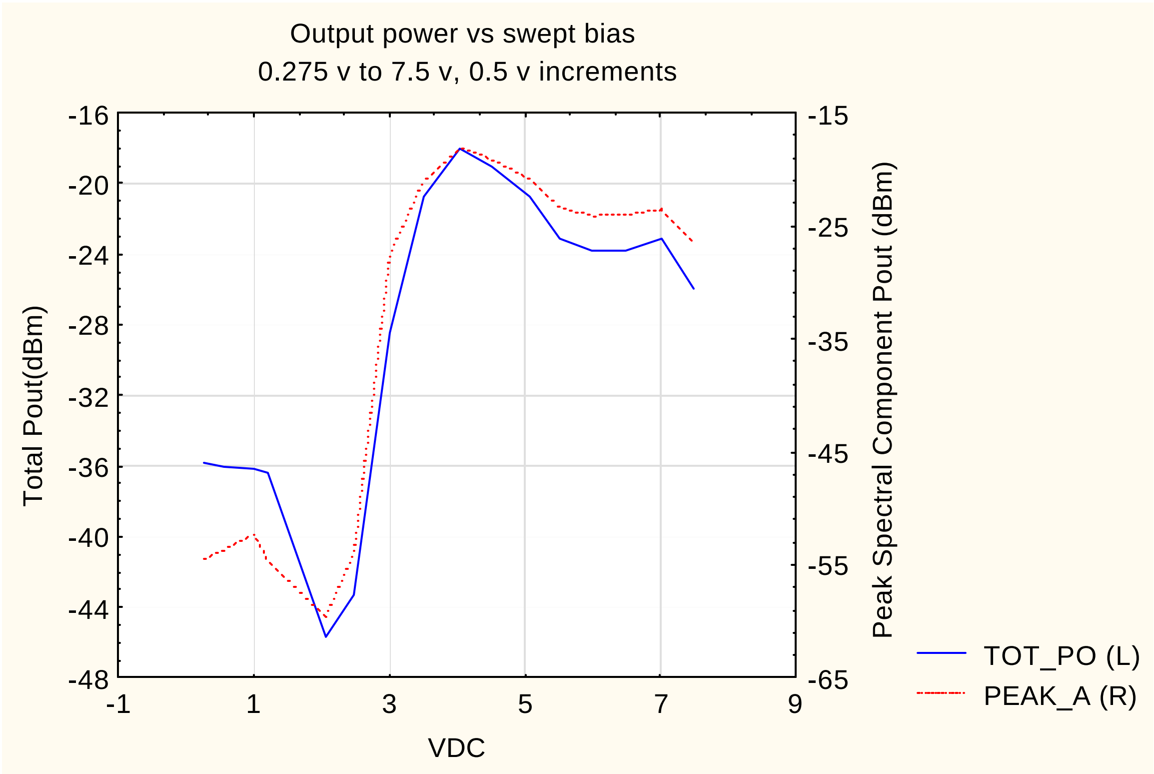


Table 1

PEAK_A is the power of the highest spectral output component. TOT_PO is the sum of the power of all the spectral components. The detected power is less than the actual power due to fiber-VCSEL misalignment. It is interesting to note that divergence of the two curves at the low and high ends of the bias conditions

2. Characteristics of the VCSEL-on-diamond.

The following charts summarize the 41 days of continuous monitoring of the VCSEL-on-diamond units. One of the 4 devices (VCSEL_1) was monitored by the OSA. The other 3 devices (VCSEL_2, _5, _8) were monitored the lightwave multimeter. For the latter devices, the only parameter recorded by the LABVIEW program is total power out. The summary of the raw power out numbers is shown in Table 2

Statistical Summary of Raw Power Output Data (dBm) for VCSEL_1
Table 2

5 V bias

	Observations	Mean Pout	Minimum Pout	Maximum Pout	Std.Dev.
VCSEL_1	674	-17.6358	-18.5157	-16.9374	.284717
VCSEL_5	674	-7.7309	-8.3565	-7.4715	.084840
VCSEL_2	674	-6.4325	-6.8194	-6.0730	.194107
VCSEL_8	674	-8.4453	-8.6328	-8.2102	.114320

6.25 V bias

	Observations	Mean Pout	Minimum Pout	Maximum Pout	Std.Dev.
VCSEL_1	913	-20.3849	-21.0891	-19.7740	.155107
VCSEL_5	913	-9.5464	-9.8297	-9.3930	.059760
VCSEL_2	913	-8.4815	-8.7290	-8.0134	.126077
VCSEL_8	913	-9.1052	-9.4310	-8.6967	.144907

7.5 V bias

	Observations	Mean Pout	Minimum Pout	Maximum Pout	Std.Dev.
VCSEL_1	387	-23.5835	-24.8671	-22.7887	.498200
VCSEL_5	387	-11.8555	-12.2915	-11.5739	.123101
VCSEL_2	387	-12.3018	-12.9328	-11.9314	.156877
VCSEL_8	387	-11.4199	-12.1042	-10.9691	.199144

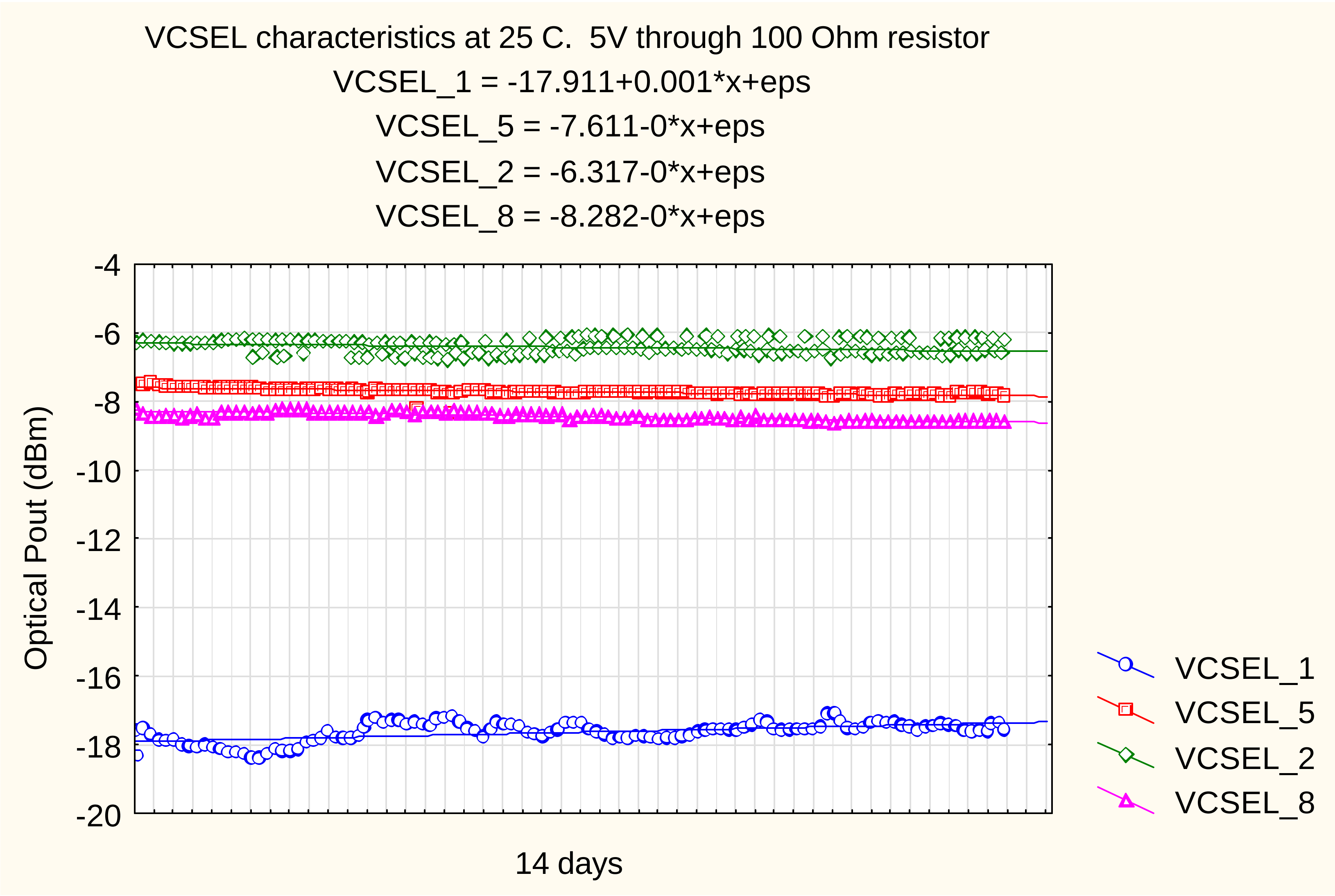


Figure 3. 5 V VCSEL data

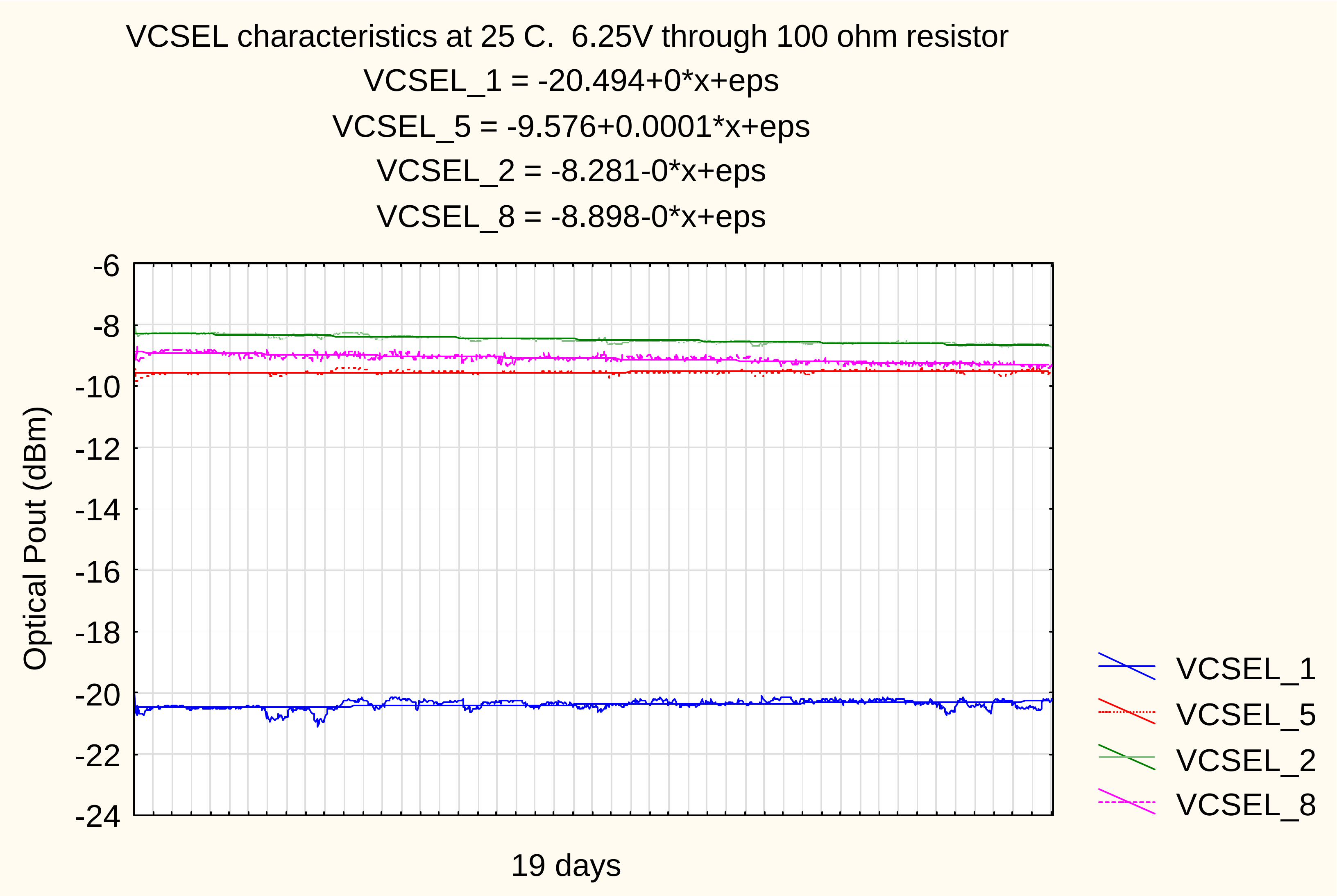


Figure 4. 6.25V VCSEL data

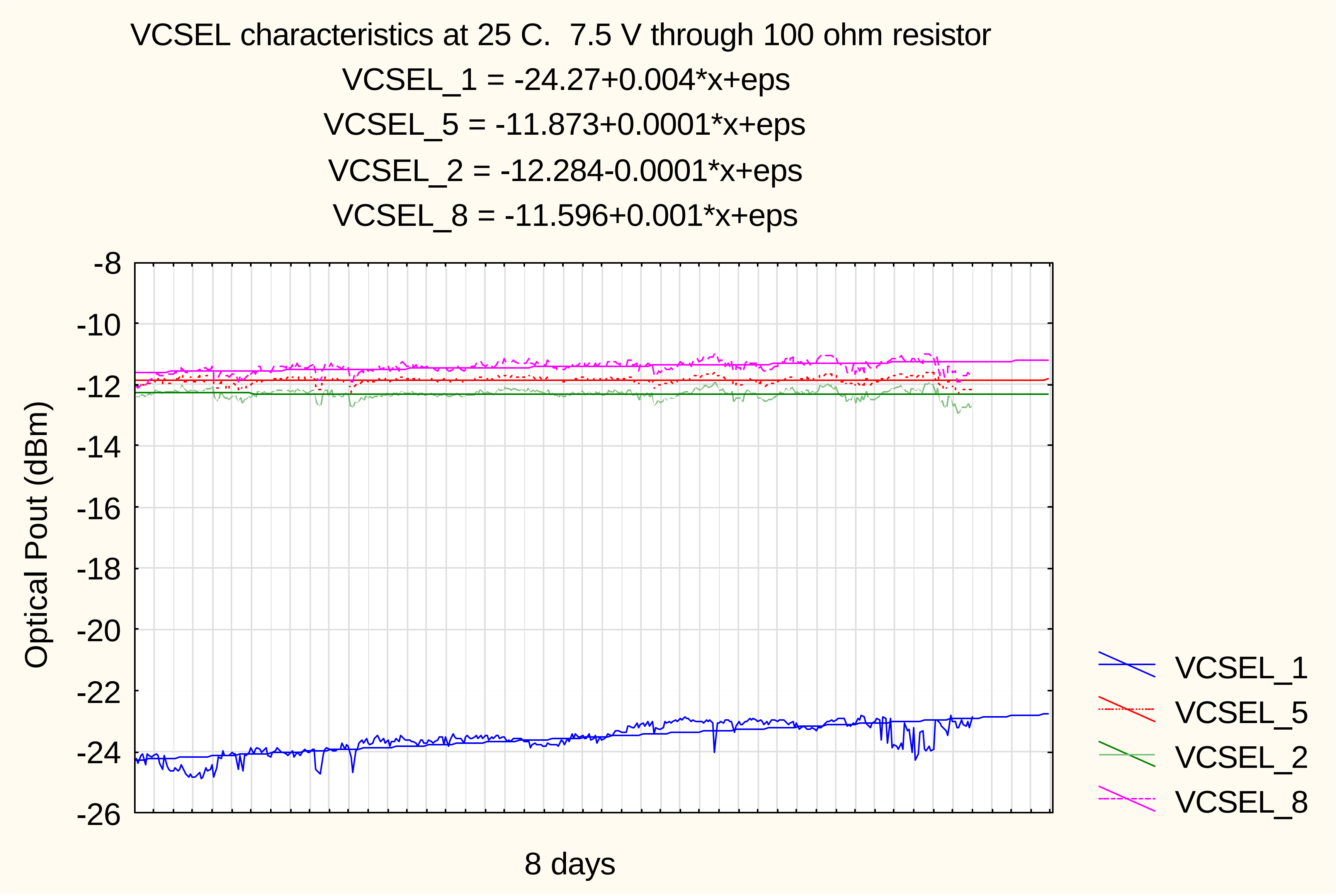


Figure 6. 7.5 V VCSEL data

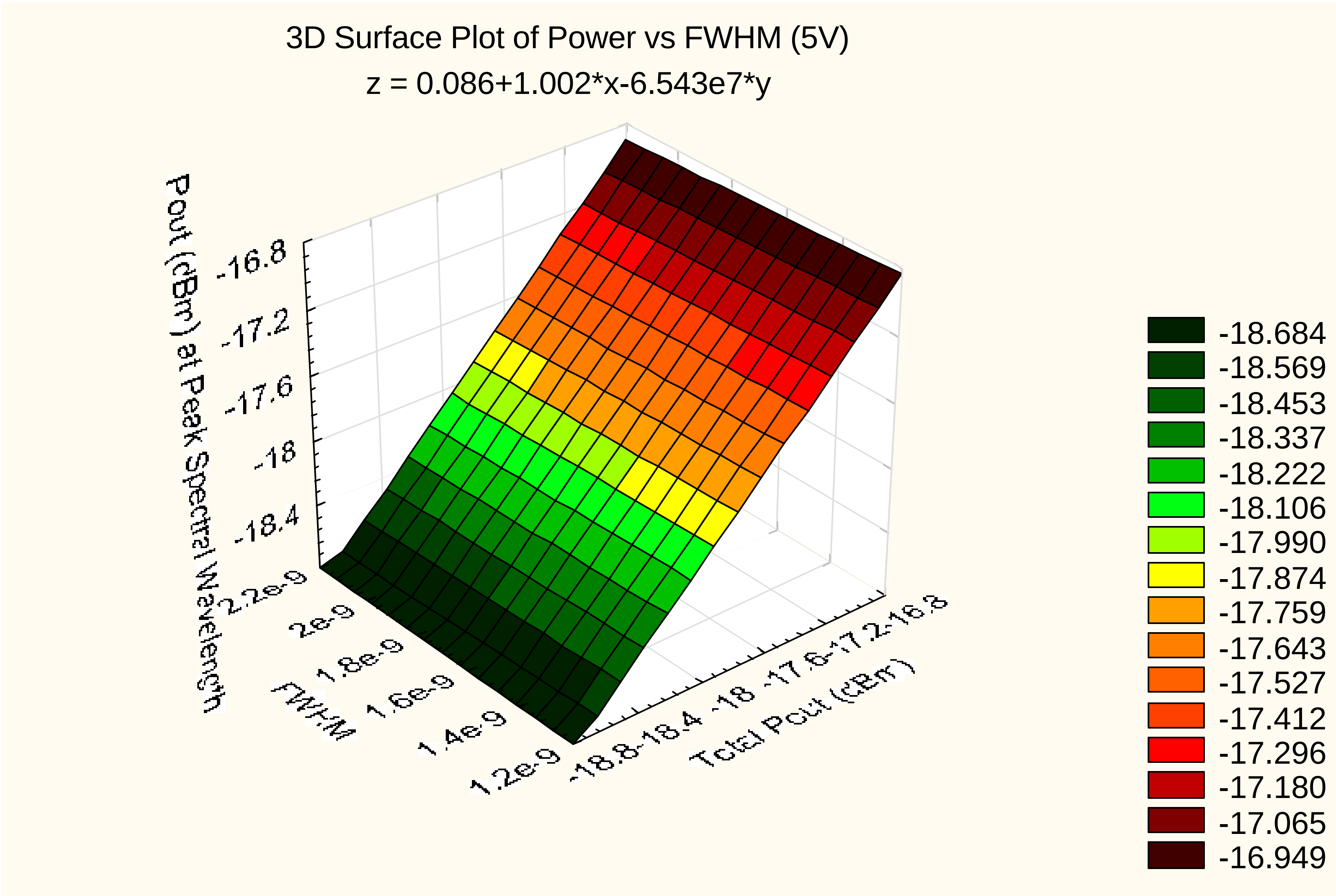


Figure 7. 3D Surface Plot of Power vs FHWM (5V)

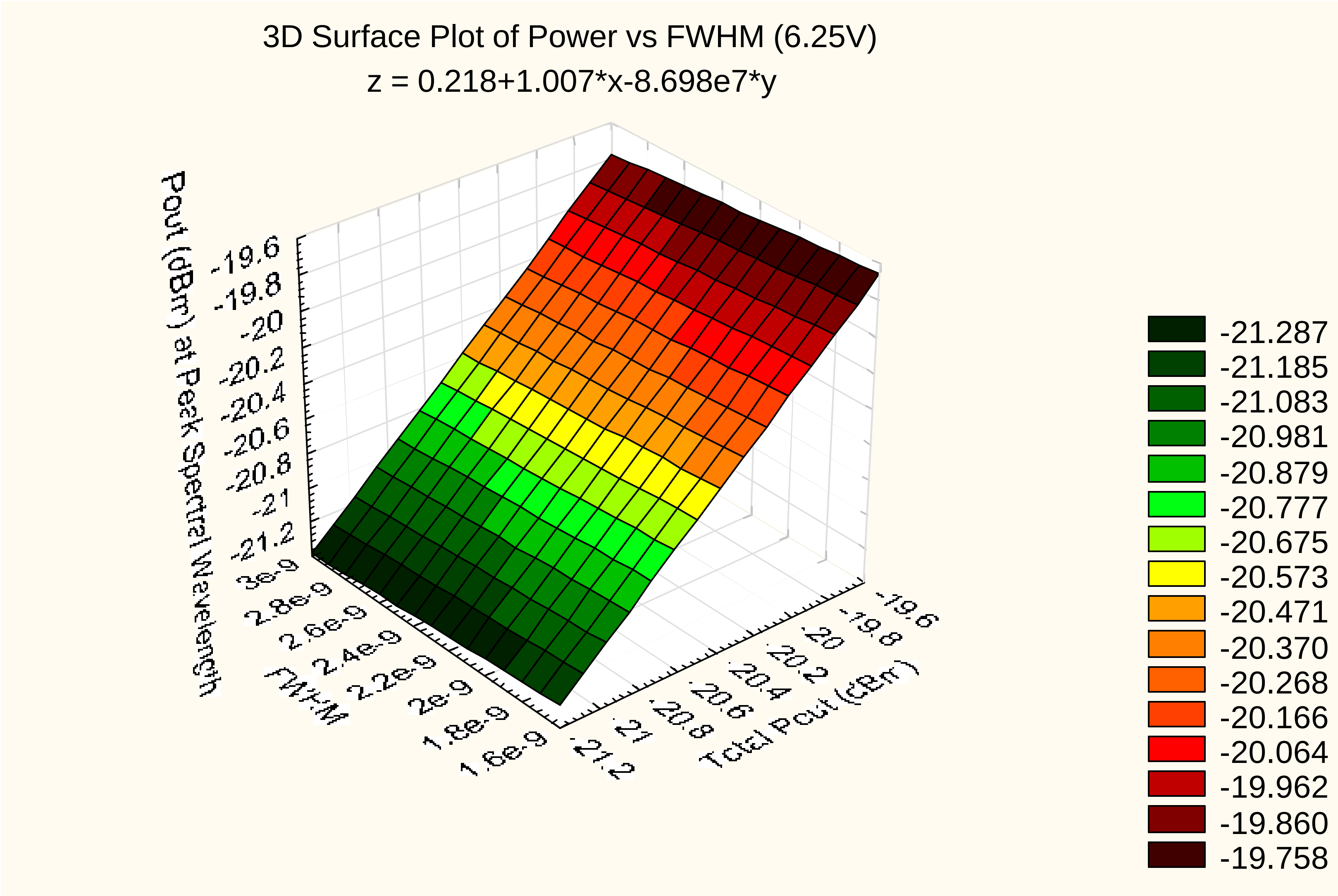


Figure 8. 3D Surface Plot of Power vs FHWM (6.25V)

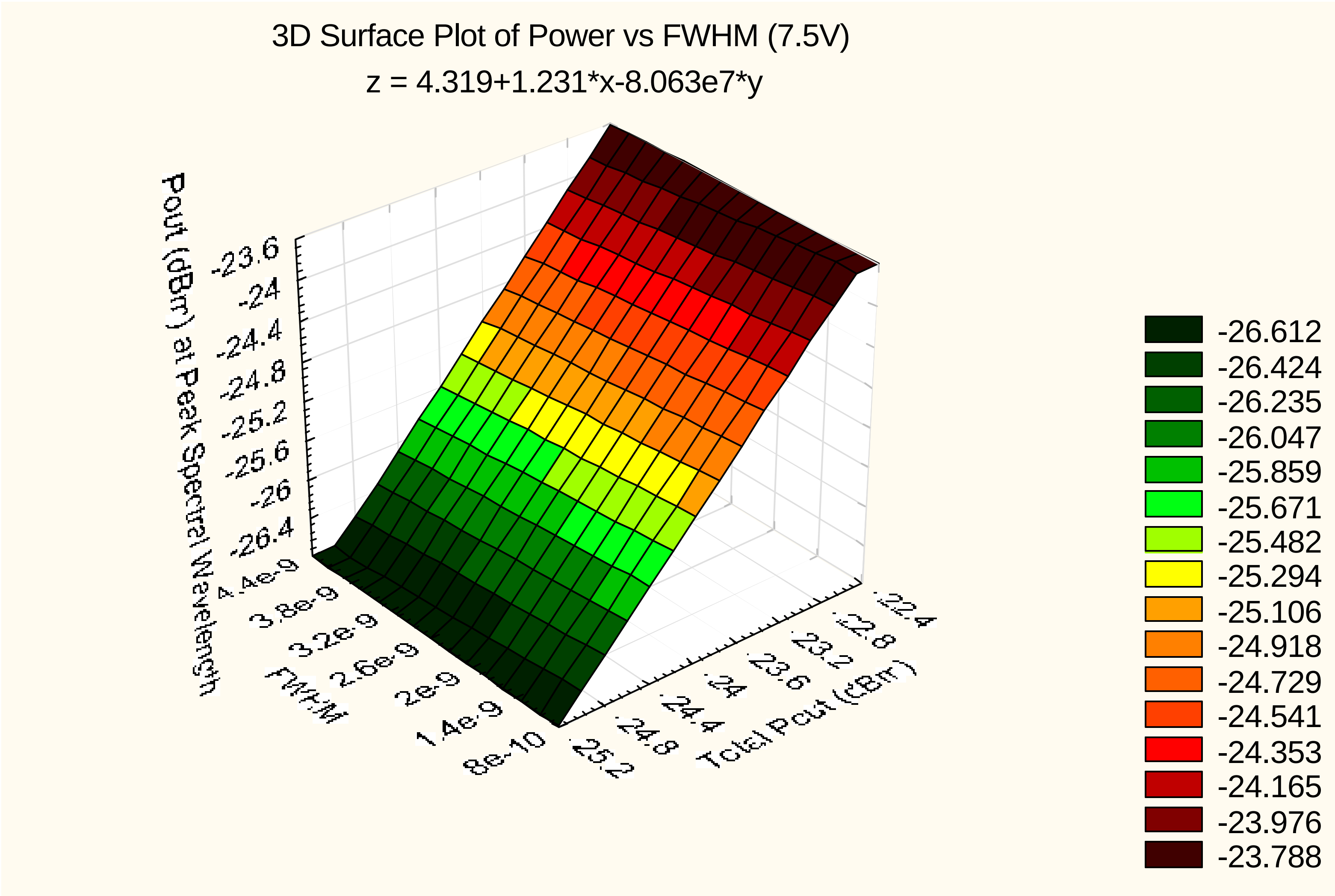


Figure 9. 3D Surface Plot of Power vs FHWM (7.5V)

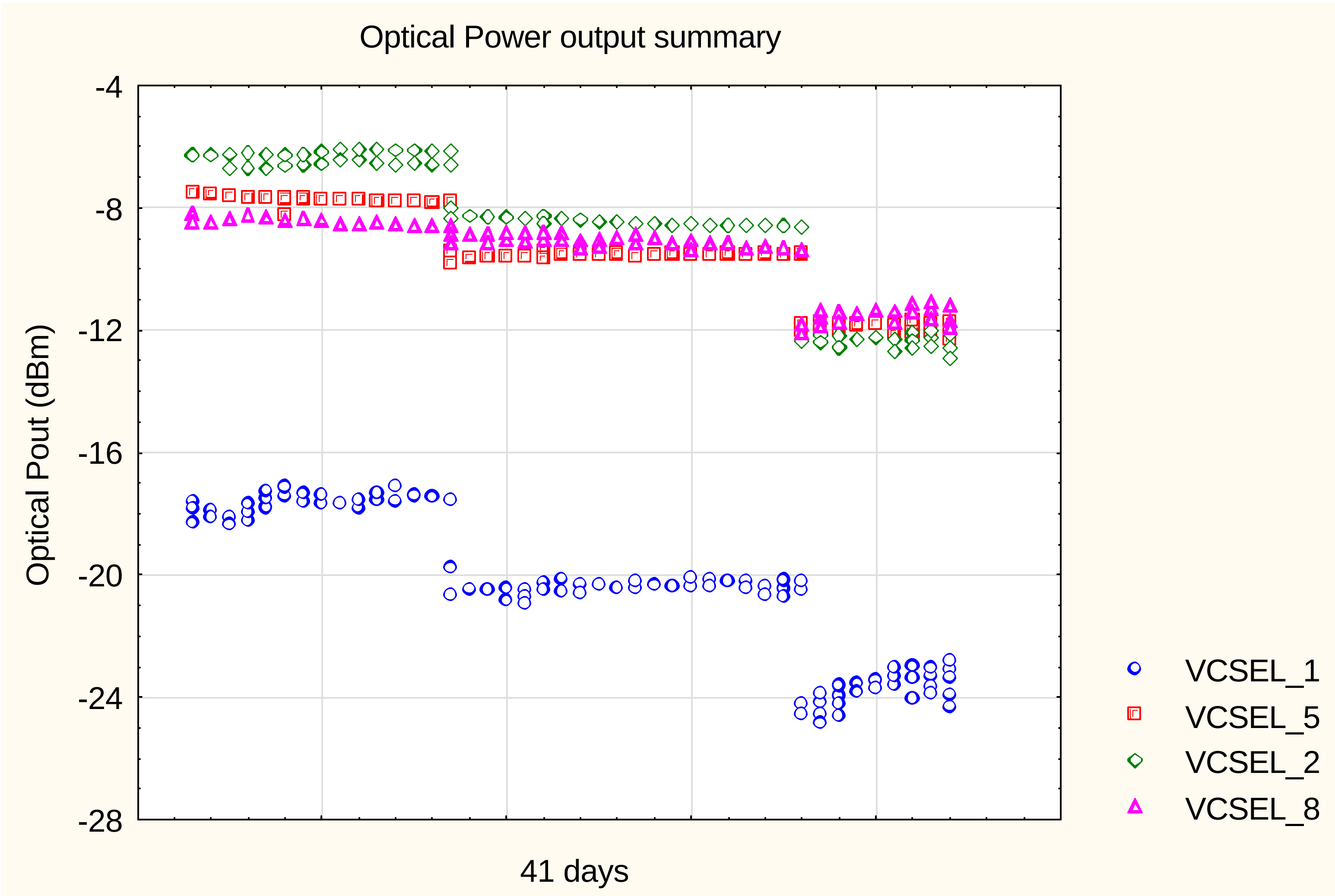


Figure 10. Optical Power output summary

3. Characteristics of the VCSELs mounted directly to Kovar headers.

The VCSELs mounted directly to the Kovar headers exhibited a power slump over time. After 2 days at 6.25 V, all 4 devices stopped exhibiting any power output at 850nm.

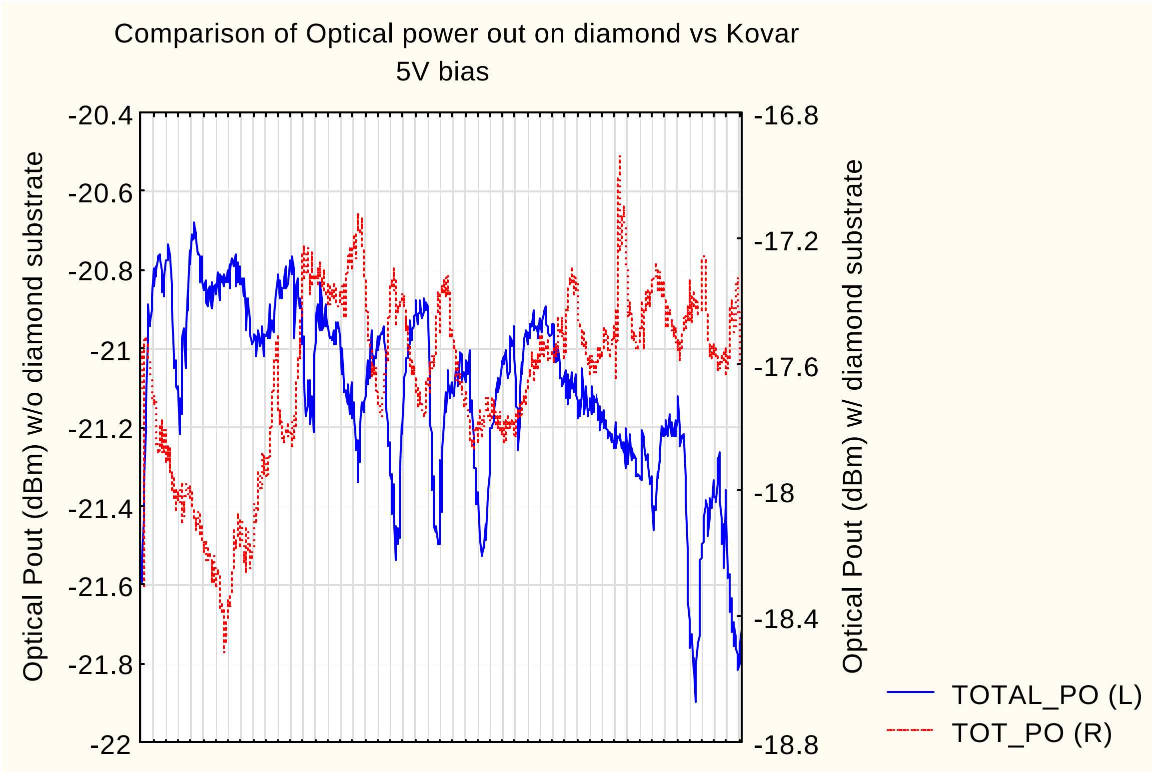


Figure 11. Comparison of Optical power out on diamond vs Kovar substrate

Table 3

Statistical Comparison of Output power data (dBm) for VCSEL mounted to diamond substrate vs Kovar header over the same number of observations

	Observations	Mean Pout	Minimum Pout	Maximum Pout	Variance	Std.Dev.
PEAK_A	674	-21.2620	-22.1000	-20.8000	.058823	.242534
TOTAL_PO	674	-21.1051	-21.8966	-20.6775	.055431	.235438
PEAK_B	674	-17.7111	-18.6000	-17.0000	.084051	.289916
TOT_PO	674	-17.6358	-18.5157	-16.9374	.081063	.284717

PEAK_A = Peak power of primary spectral peak for Kovar mounted sample
TOTAL_PO = Total power output for Kovar mounted sample
PEAK_B = Peak power of primary spectral peak for diamond mounted sample
TOT_PO = Total power out for diamond mounted sample

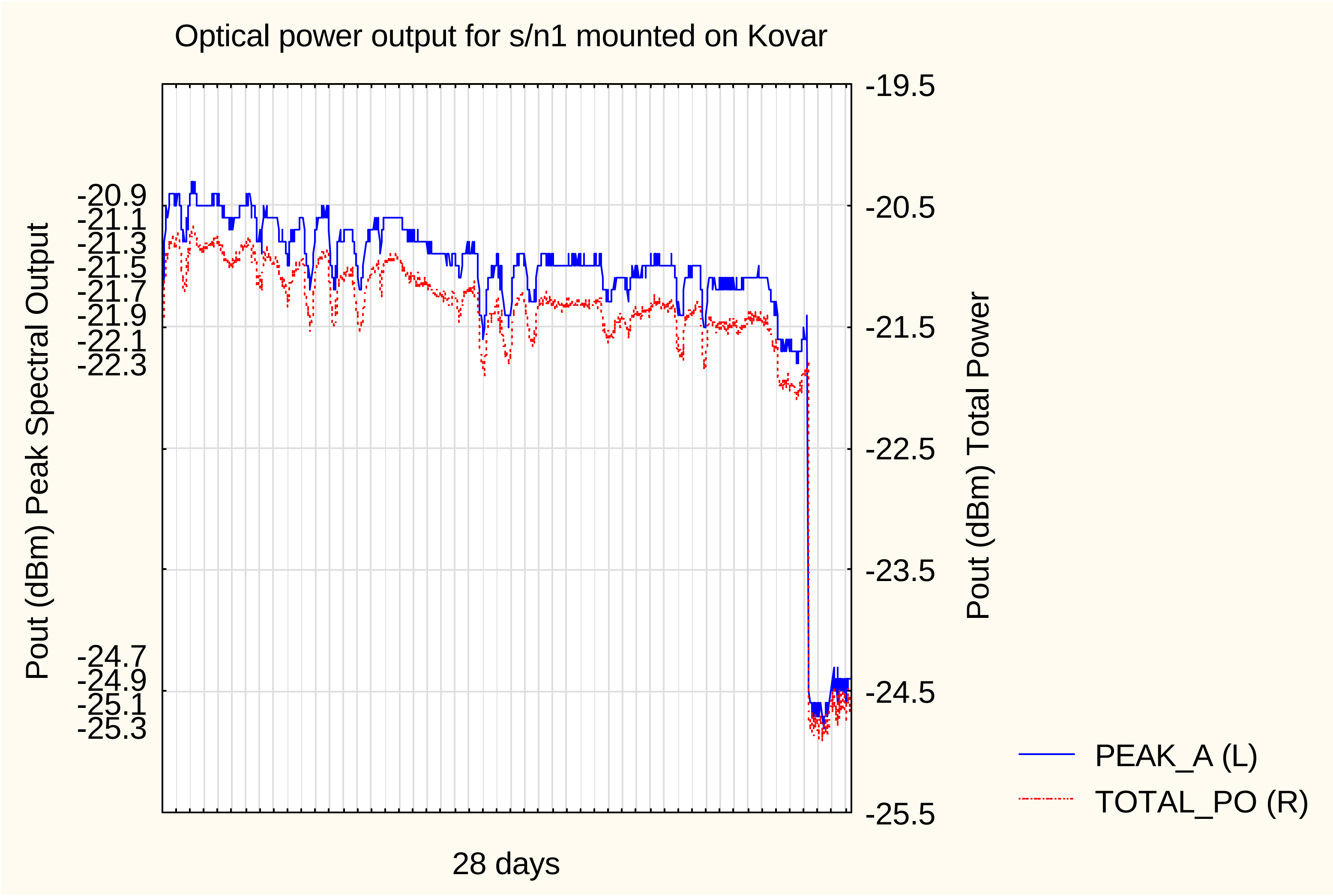


Figure 12. Optical power output for s/n 1 mounted on Kovar

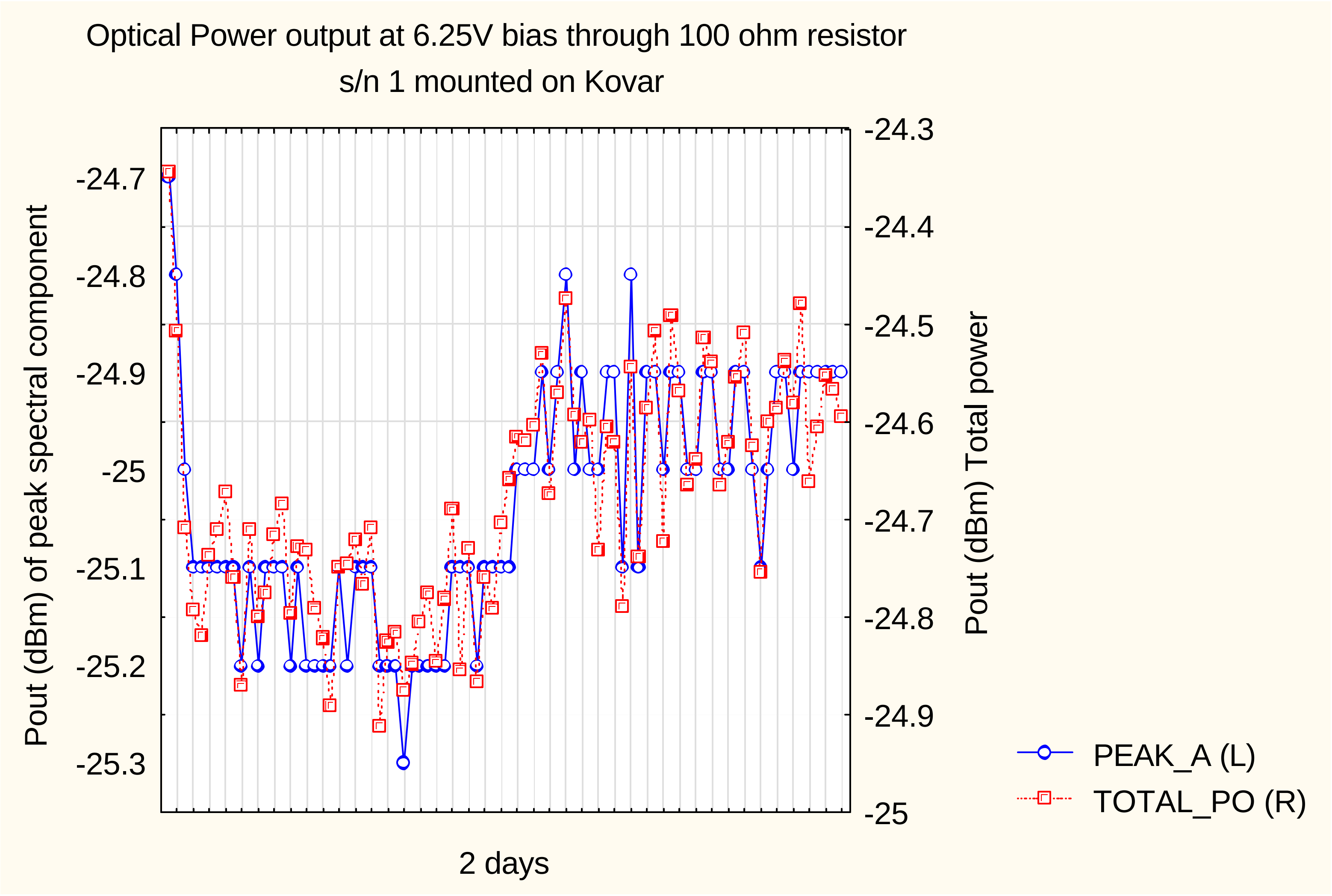


Figure 13. Optical power for S/N 1 at 6.25 V mounted on Kovar

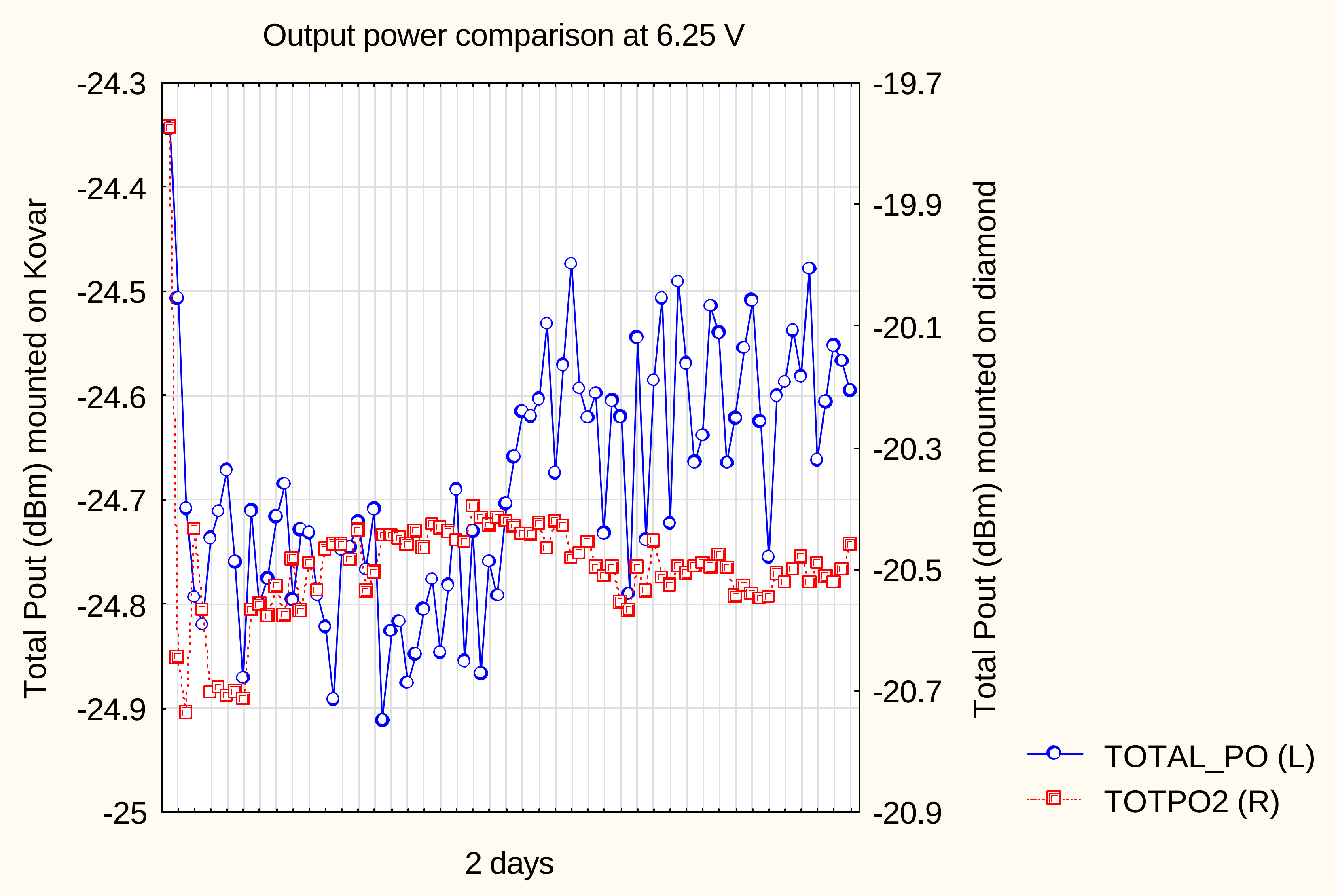


Figure 14. Output power comparison at 6.25 V for diamond and Kovar mounting

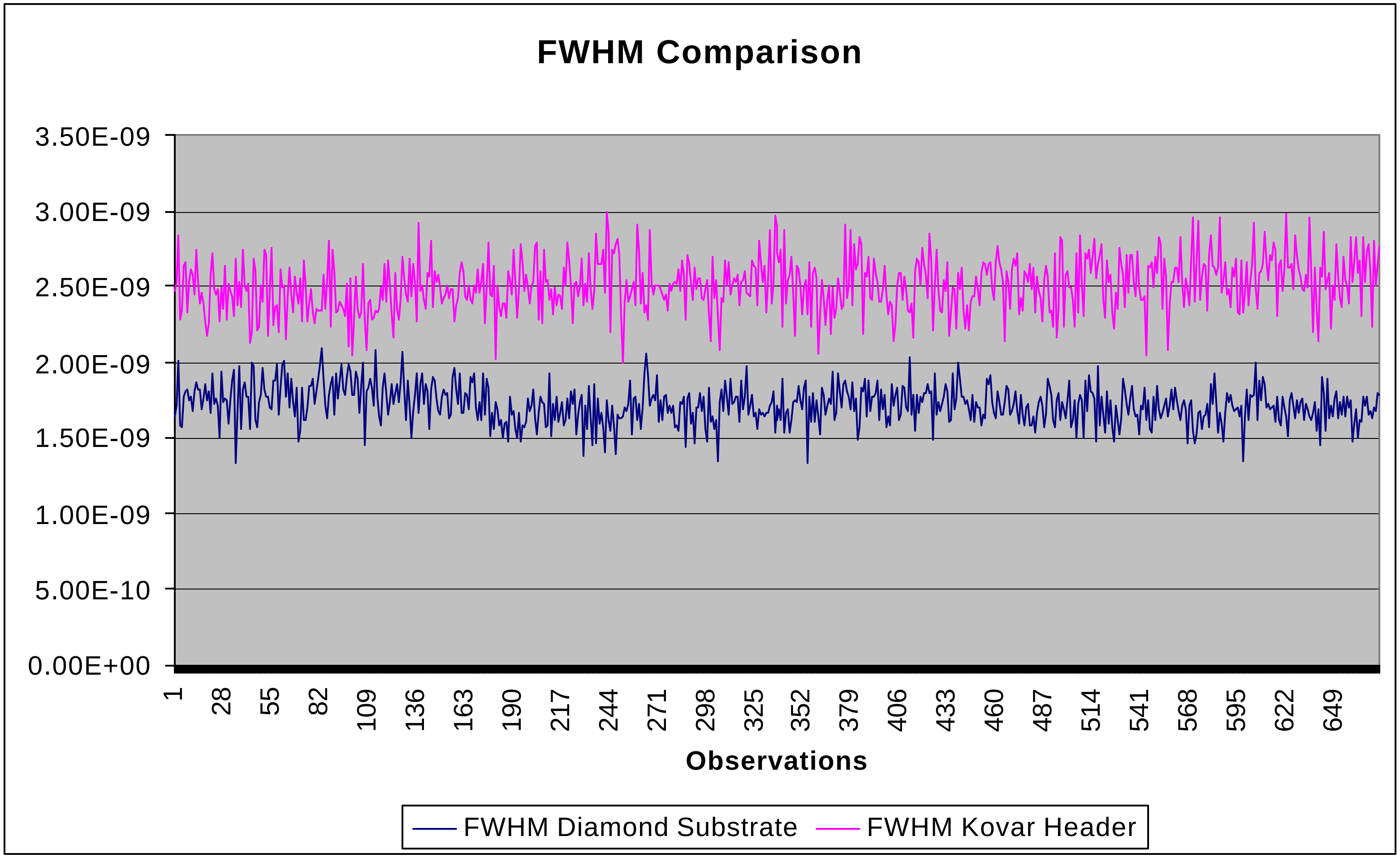


Figure 15. Full Width at Half Max comparison between diamond mounted sample and kovar mounted sample.

FWHM = 2.355 σ

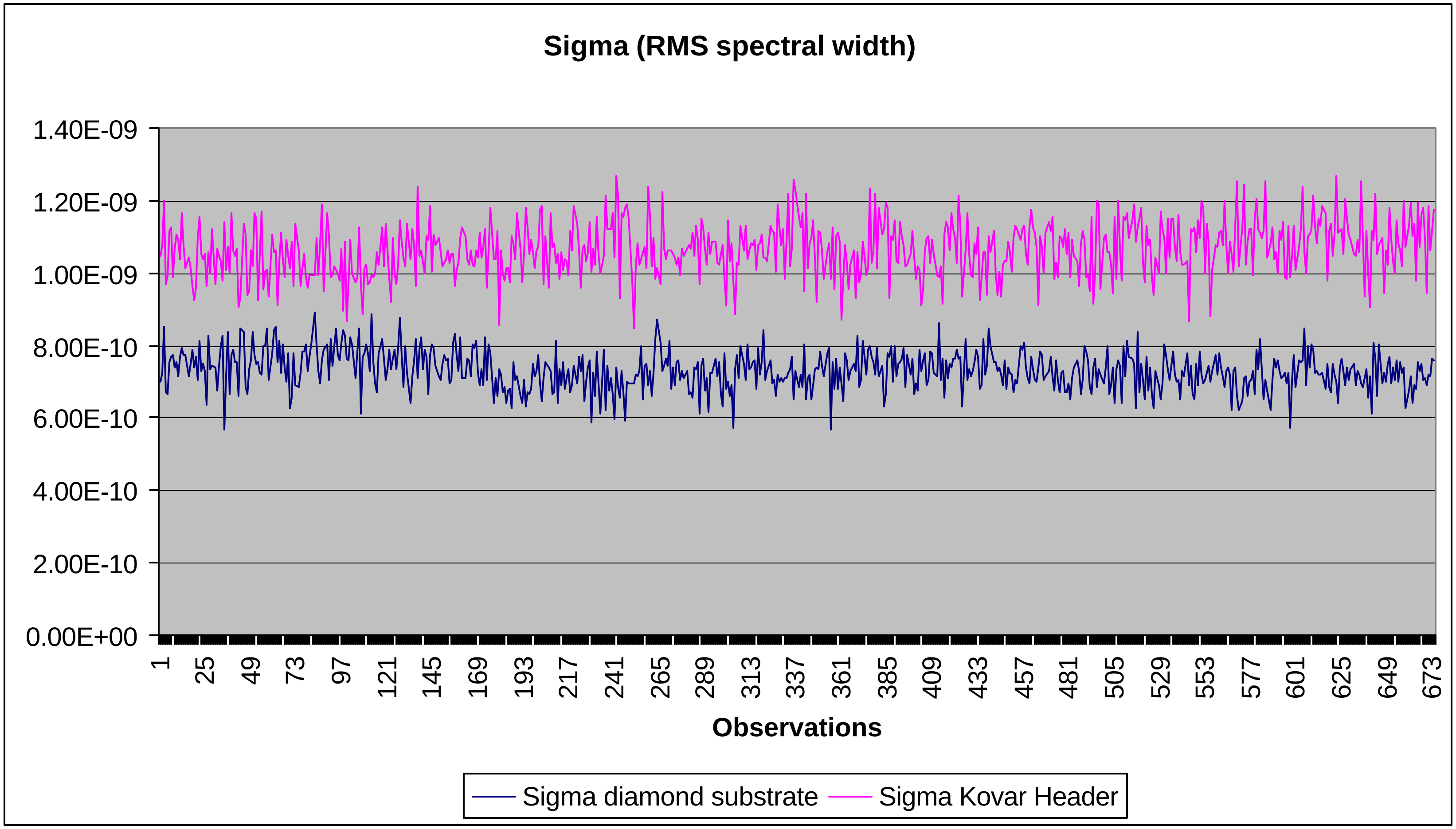


Figure 16. Sigma comparison between diamond mounted sample and kovar mounted sample.

$\sigma = (\Sigma\, P_{i,\, i=1,,n}(\lambda_i - \lambda_{mean})^2/P_{tot})^{0.5}$

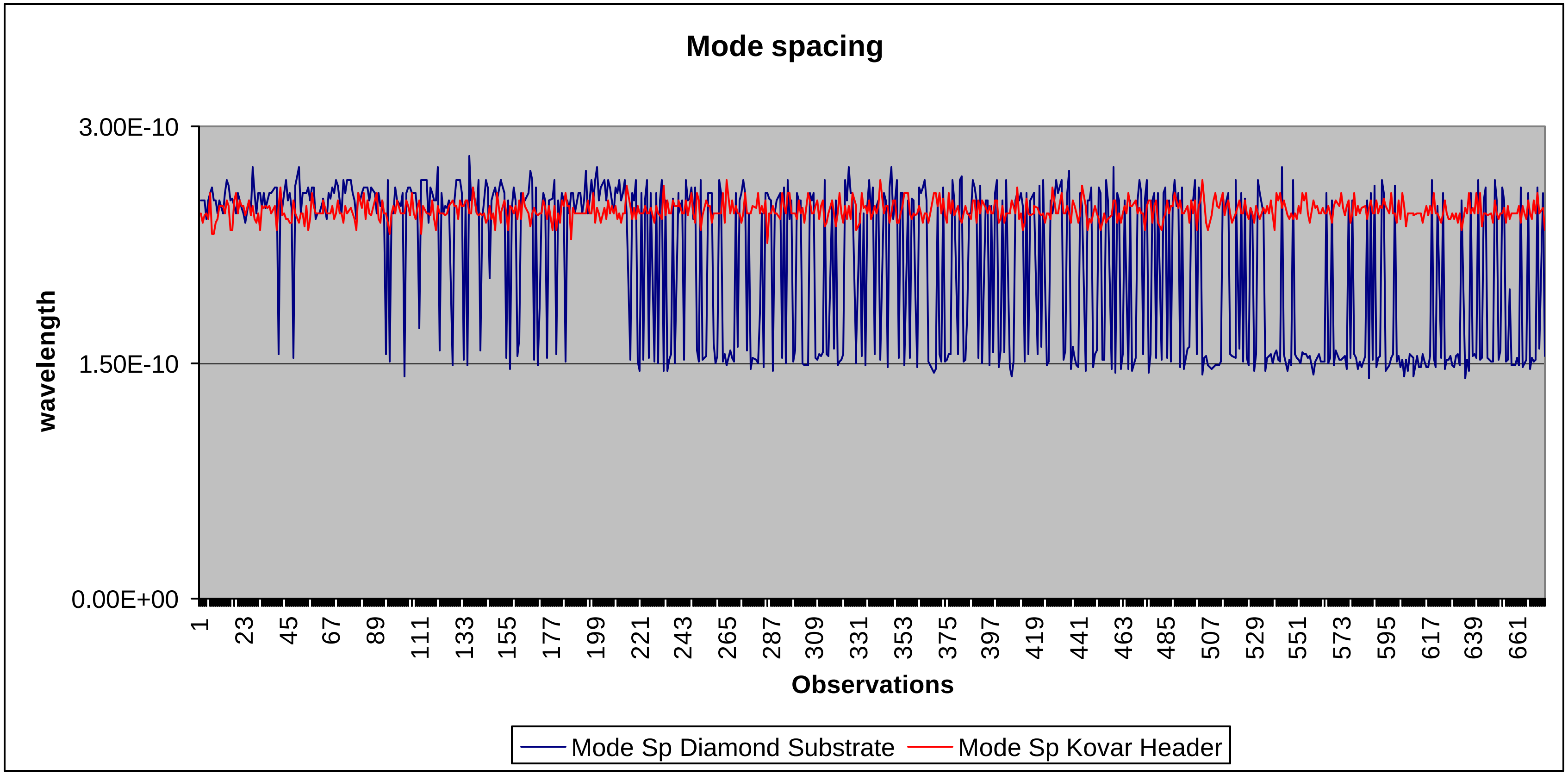


Figure 17. Mode Spacing comparison between diamond mounted sample and kovar header sample.

Mode spacing is the average wavelength spacing between spectral components of the VCSEL

4. Wavelength shifting of VCSELs.

The comparison of the spectral performance of the VCSELs on diamond versus Kovar demonstrated provided two results of note. When observed over comparable period at 5V, the VCSELs on diamond had slightly better spectral stabilty. The VCSEL on Kovar had a small blue shift over time. Statisically, the variation between the two was small as shown in table 4.

Diamond	Diamond	Kovar	Kovar
Mean Wavelength std dev	Peak Wavelength std dev	Mean Wavelength std dev	Peak Wavelength std dev
3.31272E-11	3.23E-11	4.16378E-11	3.99E-11

Table 4. Standard deviation of wavelength stability of diamond and Kovar mounted units.

The VCSEL mounted on diamond exhibited 6 abrupt shifts in mean wavelength during the 41 days of testing. Three of the shifts correlated to increases in the bias supplies. Three did not correspond to any change in the test conditions. The shifts are both higher and lower in wavelength. Incidentally, the peak wavelength exhibited only 3 shifts, each occuring at bias increase and each shift was a red shift. The VCSEL mounted on Kovar exhibited one wavelength shift, corresponding to the increase in bias voltage from 5V to 6.25 volts. There is insufficient data to draw any conclusions about the wavelength shifting over than the appearance of mode shifts within the VCLSEL. Additional characterization on a wider sample population and some knowledge of the VCSEL construction would be required.

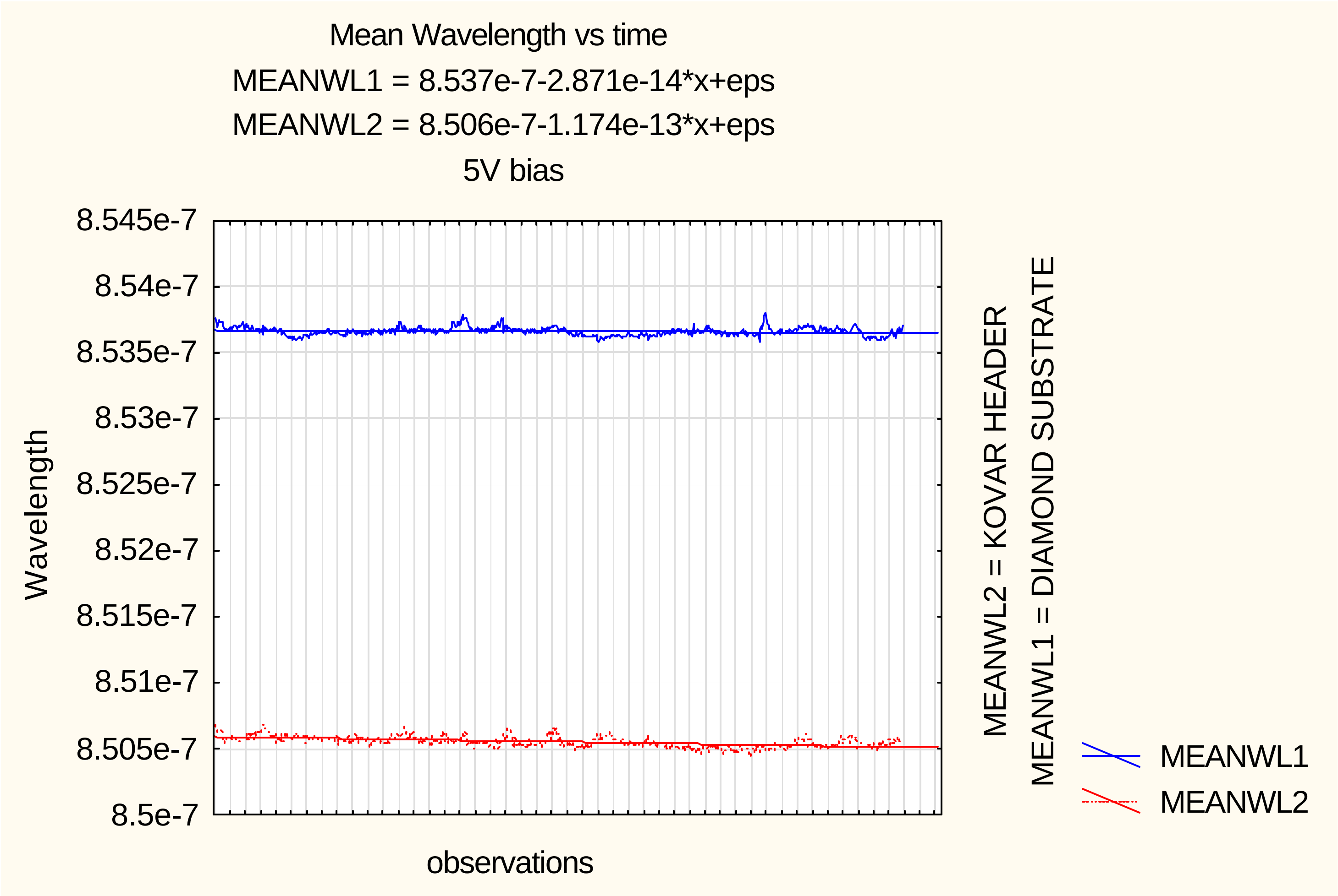


Figure 18. Mean wavelength vs time at 5V

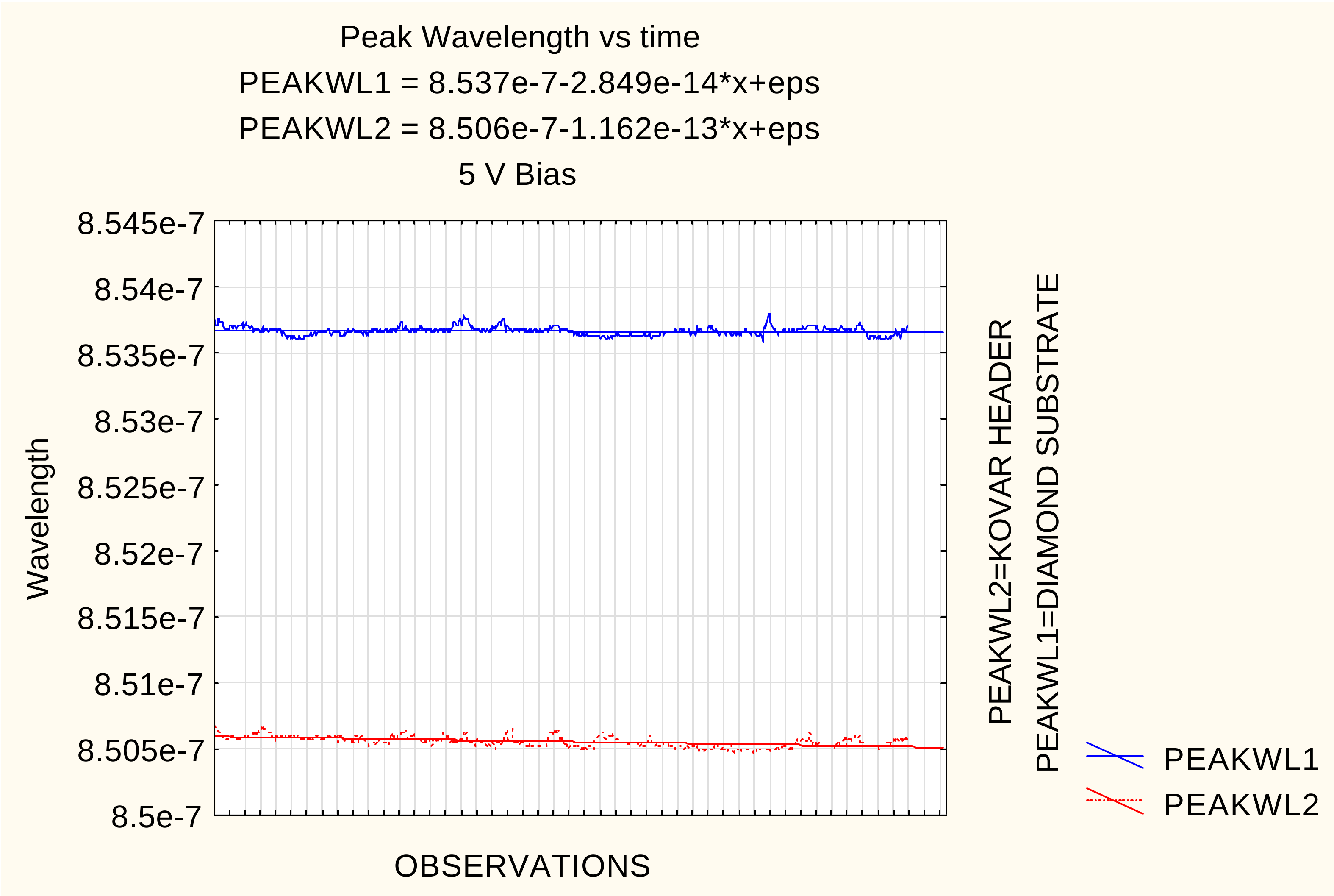


Figure 19. Peak wavelength vs. time at 5V

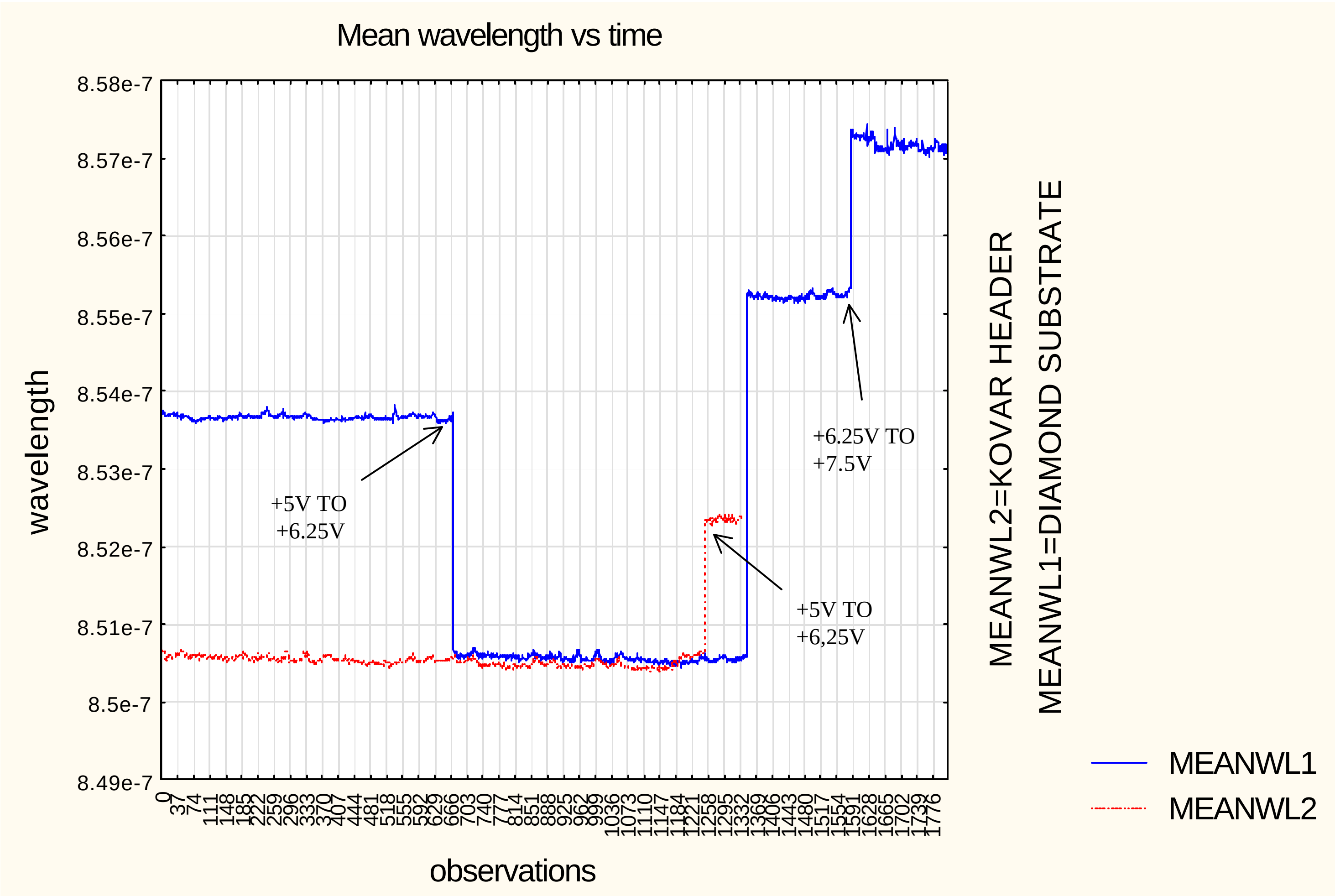


Figure 20. Mean wavelength vs. time for the entire test

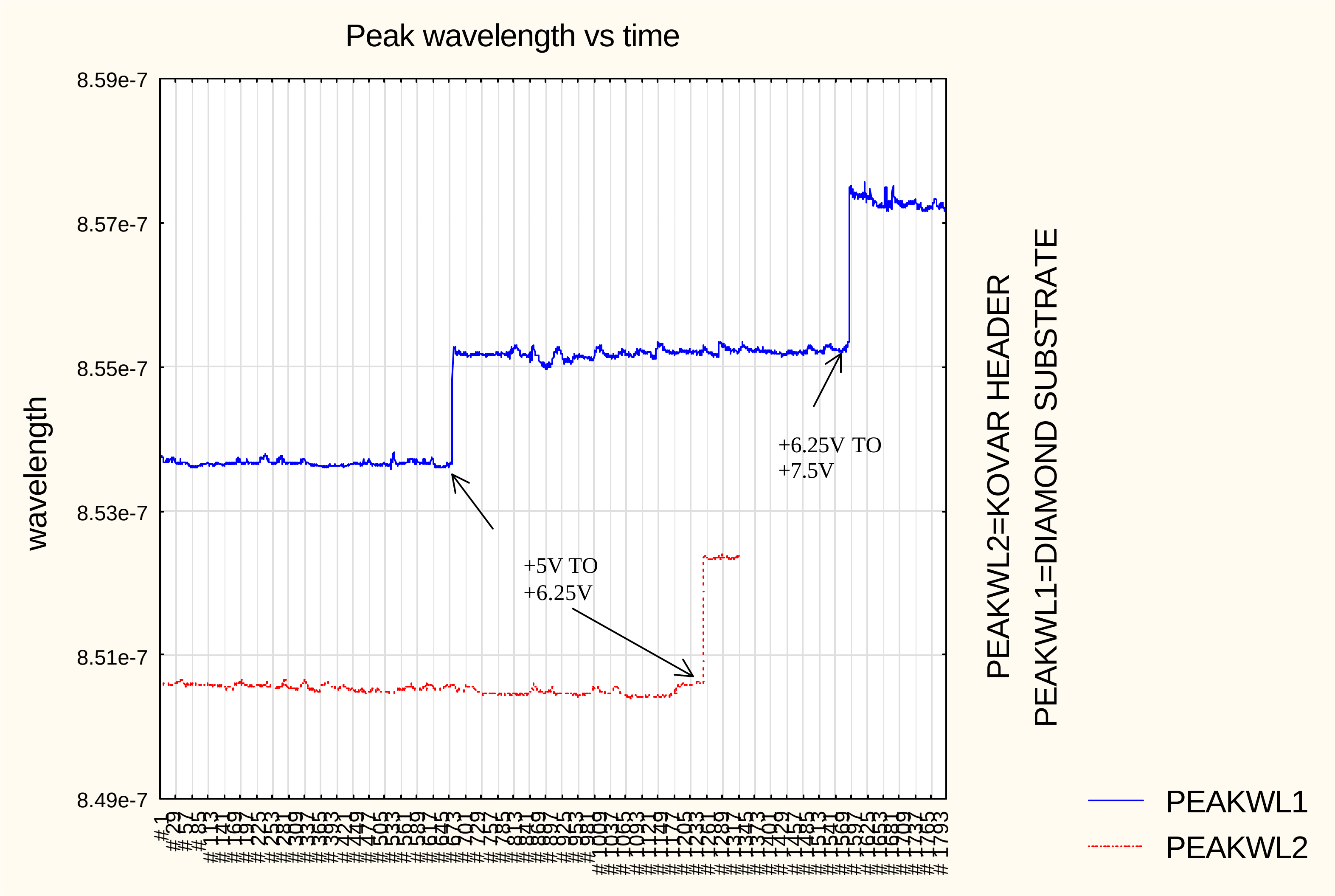
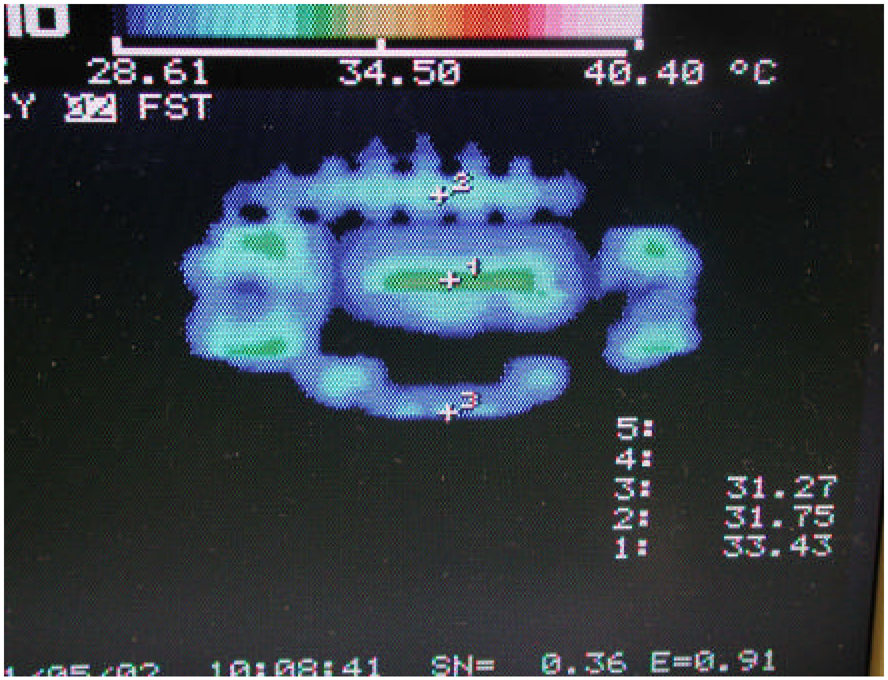
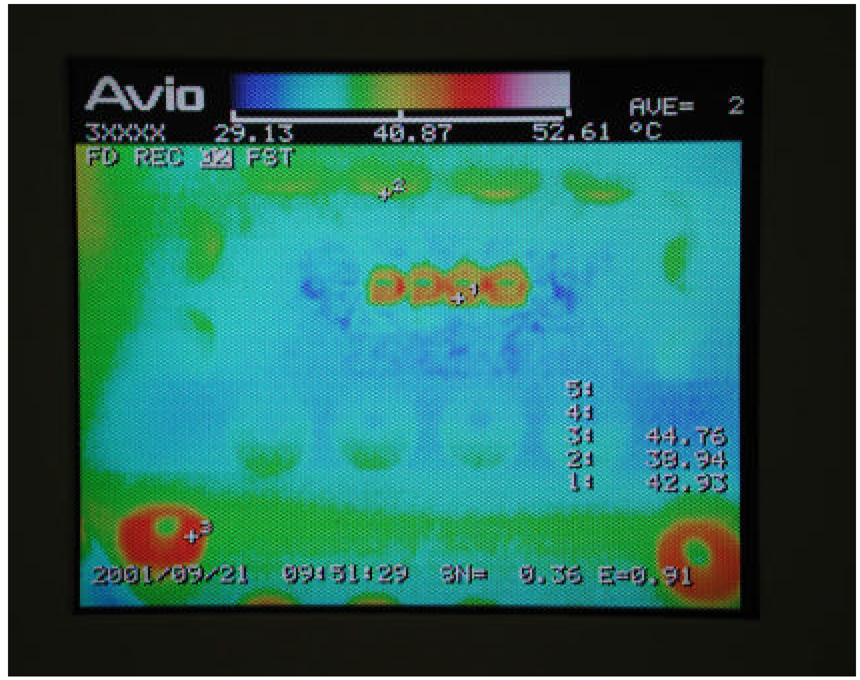


Figure 21. Peak wavelength vs. time for the entire test

Figure 22
Thermal images at 5 V

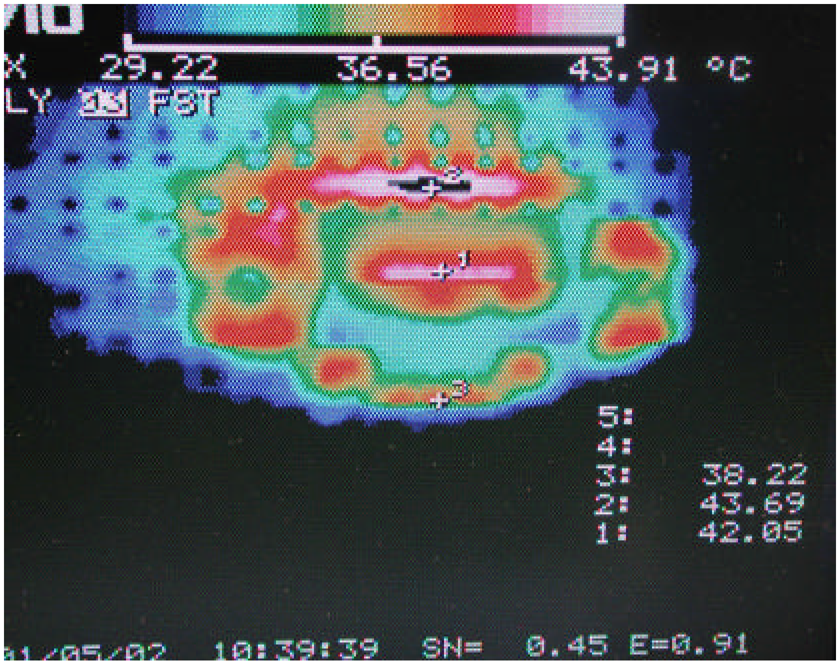


Diamond



Kovar Header

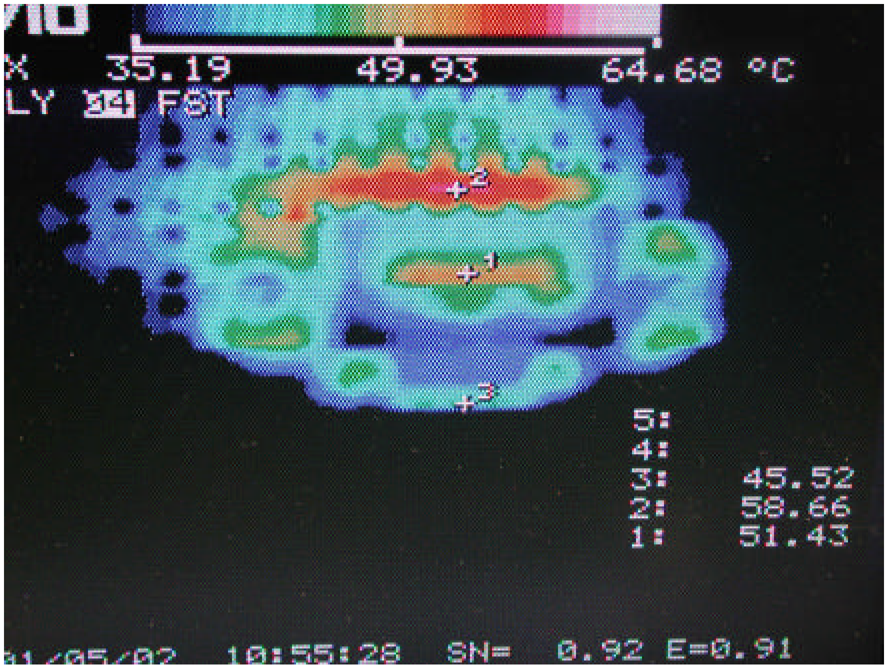
Figure 23
Thermal images at 6.25 V



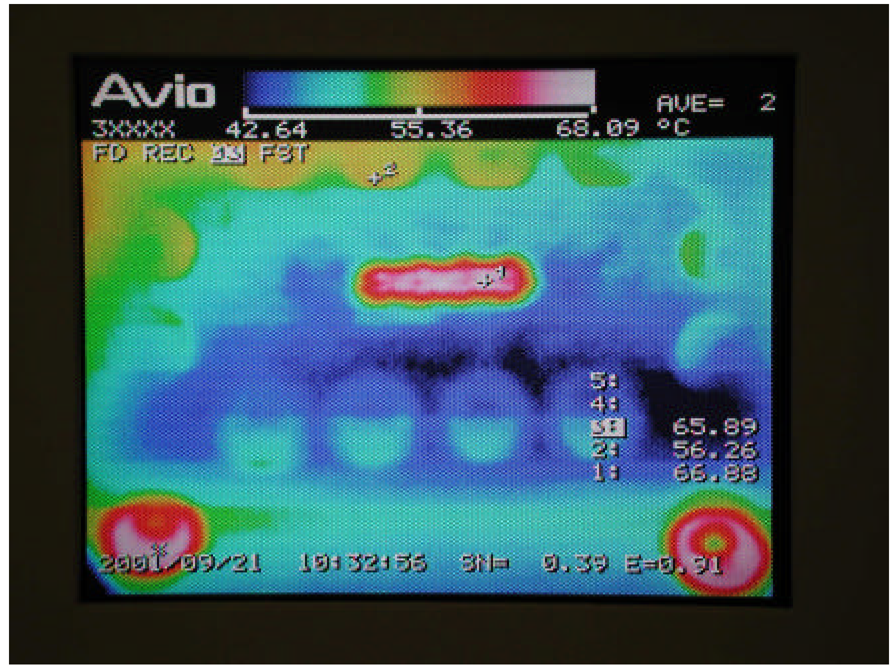
Diamond

Kovar Header

Figure 24
Thermal images at 7.5 V



Diamond



Kovar Header

5.0 Conclusions

The VCSELs mounted on diamond were capable of being overdriven at higher current levels without damage. The highly accelerated voltage and current stress demonstrated that the diamond substrate provided a significant margin of thermal mitigation. VCSELs were driven at up to 3X the manufacturers recommended maximum instantaneous operating current and 10X the typical threshold current. Key parameters from the data sheet are summarized below in Table 4.

Parameter	Rating	Min	Typical	Max
Max Continous Operating Current	20mA			
Max Instantaneous Operating Current	25mA			
Peak Wavelength		830nm	850nm	860nm
Threshold Current		5mA	8mA	9mA
Output Power at 20mA		3dBm	7.8dBm	10dBm
Operating Voltage at 9mA		1.6V	2.2V	2.3V

Table 4. Key Paramaters from Emcore VCSEL data sheet (p/n 8085-1000)

Additional testing is required to assess the effects of screening on the long term reliability of VCSEL mounted on diamond. Additional characterization of wavelength stability in current generation VCSEL arrays is also warranted.